Risk Assessment at the Cosmetic Product Manufacturer by Expert Judgment Method

A N Vtorushina, E V Larionova[a], I L Mezenceva, E D Nikonova

Ecology and Human Safety Department, Tomsk Polytechnic University
Lenin av. 34, Tomsk, Russia, 634050

E-mail: [a] evl@tpu.ru

Abstract. A case study was performed in a cosmetic product manufacturer. We have identified the main risk factors of occupational accidents and their causes. Risk of accidents is assessed by the expert judgment method. Event tree for the most probable accident is built and recommendations on improvement of occupational health and safety protection system at the cosmetic product manufacturer are developed. The results of this paper can be used to develop actions to improve the occupational safety and health system in the chemical industry.

1. Introduction

Professional risk management is a part of occupational health and safety management system and refers to organization and sustention of preventive actions focused on optimization of hazards and risks such as prevention of accidents, injuries and occupational diseases. Professional risk management includes complex of actions to identify, assess and reduce the level of professional risk. Implementation of professional risk management is essential to the chemical industry because of increasing hazards of modern process and facilities and more over harmful substances can emit to air or discharge to water or dispose with waste [1,2]. Therefore professional risk management must be a core of preventive health and safety protection system in the chemical industry. There is a variety of methods that have been developed to analyse risk originating from hazardous facilities and substances. Good review of qualitative, semi-quantitative, quantitative and hybrid methods of risk assessment can be found in [3]. Papers [1,2,4] are devoted to analysis of risk assessment methods applied in the chemical industry.

In case of time series accident data over several years are not available the expert judgement method can be recommended for risk assessment [5]. The expert judgement method makes valuable use of prior knowledge and experience of experts and can be made easily and speedily. The disadvantage, however, is that it relies on subjective opinion, hunch and intuition of experts. Limitation of the method is the uncertainties associated with the results [6,7].

The aim of this work is to assess risk of accidents by the expert judgement method and to develop recommendation on improvement of occupational health and safety protection system in a cosmetic product manufacturer. The company is located in Russia, Altai region. The main activity of the company is the manufacture of perfumes, cosmetics and household chemicals.

Legislation in Russia establishes the requirements to risk assessment of accidents and their threats of occurrence, to analysis of the causes of accidents, their factors and risks associated with them, as

well as the selection of risk analysis methods for subsequent evaluation. It is known that the reasons for the implementation of accident and injury was a fault of the process equipment, as well as the human factor such as the wrong organization of work, carelessness, neglect of use of personal protection equipment [8]. However, in the Russian legislation in the field of risk analysis the human risk factors are not considered. Thus, the relevant issue is the harmonization of Russian legislation with international standards and practice in the field of risk assessment, such as OHSAS 18001, ILO-OSH 2001, AFS 2001 (AFS 2008:15), ISO 31010:2011.

This paper consider the risks arising both at the fault of process equipment due to its failure or malfunction; and, the human factor, risks associated with the neglect of safety regulations, ignoring the use of personal protective equipment, violation of fire and electrical safety rules.

2. Results and discussion

2.1. Risk assessment of accidents by expert judgment method

To evaluate the risk of accidents in the cosmetic product manufacturer the expert judgment method is used. We used the individual opinions of the expert group members based on the preliminary gathering of information from experts that were interviewed independently of each other with the following treatment of the data. In this work a questionnaire method is used. For this purpose the questionnaire is developed. Experts was asked to rate the probability of the events and the severity of accidents on a scale from 1 to 5. According to the process features there are following possible accidents:

1. Electric shock due to the failure of process equipment or insulation.
2. Thermal injure received from the hot components of process equipment.
3. Falling from a height in warehouse.
4. Injuries received from the rotating parts of process equipment.
5. Chemical injury, caused by accident in production process or in analytical laboratory.
6. Injuries caused by the explosion of the equipment which is under pressure.

There are no objective criteria for proclaiming a person an expert [9]. Experts have been selected as objectively as possible among professionals who really stand out for their knowledge and experience.

Risk is evaluated as the product of the probability by the severity of accident. The assessment of accident probability and severity is exposed on a 5-point scale, which is presented in Table 1.

Table 1 – Evaluation scale

Probability of the event	The accident severity	Scale
Very low, the event is unlikely to occur (the probability is from 1 to 20%);	Minor injuries, no need to go to the medical center	1
Low, the event is unlikely to occur (the probability is from 21 to 40%)	Moderate injuries without disability, appealing to the medical center	2
Middle, the event is likely to occur (the probability is from 41 to 60%);	Accident at workplace with a temporary disability	3
High, the event is very likely to occur (the probability is from 61 to 80%)	Accident at workplace with a heavy injuries, with full disability (amputation, etc.)	4
Very high, the event is likely to happen earlier than it is supposed (the probability is more than 80%);	Fatal accident	5

The results of the questionnaire of experts are presented in Table 2. Then scores of risk are ranked provided that the rank of one is less probable event and the rank of six is the most likely event. If scores of risk received the same ranks, then they were replaced by "standardized ranks" calculated as

the average amount of ranks divided among the ranks with the same incidents. The results of the ranking of risk scores are presented in Table 3.

Table 2 – Results of scoping of the probability accident (P), the accident severity (S) and the risk (R)

Expert	Accident																	
	1			2			3			4			5			6		
	P	S	R	P	S	R	P	S	R	P	S	R	P	S	R	P	S	R
1	3	1	**3**	1	1	**1**	3	3	**9**	2	3	**6**	2	4	**8**	1	2	**2**
2	1	1	**1**	3	2	**6**	2	4	**8**	3	4	**12**	3	3	**9**	2	5	**10**
3	2	2	**4**	1	1	**1**	3	3	**9**	2	5	**10**	4	3	**12**	2	4	**6**
4	3	2	**6**	1	1	**1**	2	2	**4**	3	3	**9**	3	2	**6**	1	1	**1**
5	1	3	**3**	3	3	**9**	3	4	**12**	4	2	**8**	4	5	**20**	3	3	**9**
6	1	2	**2**	1	2	**6**	3	3	**9**	2	3	**6**	4	3	**12**	2	2	**4**
7	2	1	**2**	3	2	**6**	2	1	**2**	4	3	**12**	3	3	**9**	2	4	**8**

Table 3 – Results of risk assessments ranking

Expert	Accident					
	1	2	3	4	5	6
1	3	1	6	4	5	2
2	1	2	4	6	5	3
3	2	1	4	5	6	3
4	4.5	1.5	3	6	4.5	1.5
5	1	3.5	5	2	6	3.5
6	1	2	5	4	6	3
7	1	2	1	5	4	3

Kendall's coefficient of concordance is used to assess consistency of experts' judgments. Kendall coefficient of concordance essentially denotes the average rank order correlation between the cases. If the coefficient is greater than 0.4, it is considered that the judgments of experts have the consistency [10].

In order to estimate significant differences in risk assessments of accidents Friedman ANOVA by ranks is used. In the test the null hypothesis is formulated as an equality of medians in experts' assessments on each accident. The conclusion on rejection or not rejection of the null hypothesis is done by comparing of the achieved significance level p with the fixed one $\alpha = 0.05$. Thus, if the null hypothesis is not rejected then there are only random differences between the risks of accidents. If the null hypothesis is rejected then there are significant differences between the risks of accidents.

The data processing was performed by the Statistica program. The obtained results are presented in Table 4. In addition for the visualization of the data a box plot is constructed (figure 1).

The table 4 shows that the concordance coefficient is equal to 0.59, which indicates a high consistency of experts' judgments. Friedman ANOVA results show that $p < \alpha$, therefore the null hypothesis is rejected. Thus, according to experts' judgments the risk of accidents is significantly different. As it can be seen from the figure 1 and table 4 the most likely accident is the chemical injury.

To identify the main causes and factors of the most likely events realization (that were identified earlier) it is advisable to use an event tree analysis. The algorithm of the event tree construction is the coherent definition of events following from the main event.

Table 4 – Results of Friedman ANOVA and Kendall's coefficient of concordance

ANOVA Chi Sqr. (N = 7, df = 5) = 20.66390 p = 0.00094 Coeff. of Concordance = 0.59040 Aver. rank r = 0.52213				
	Average Rank	Sum of Ranks	Mean	Std.Dev.
1	2.000000	14.00000	1.928571	1.367131
2	2.000000	14.00000	1.857143	0.852168
3	4.071429	28.50000	4.000000	1.632993
4	4.714286	33.00000	4.571429	1.397276
5	5.357143	37.50000	5.214286	0.809174
6	2.857143	20.00000	2.714286	0.698638

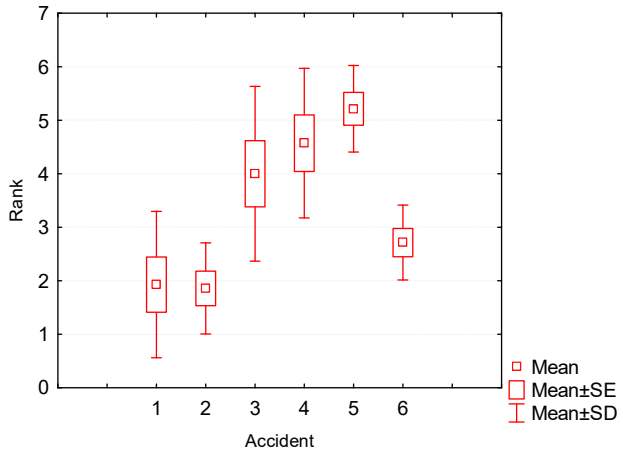

Figure 1 – Box and whisker plot of risk assessment at the cosmetic product manufacturer

Event tree provides an opportunity to strictly record the sequence of events and identify the relationship between the initiation and subsequent events, the combination of which results in the chemical injury. Thus the event tree is developed in order to model the scenario of the most likely event at the cosmetic product manufacturer (Figure 2).

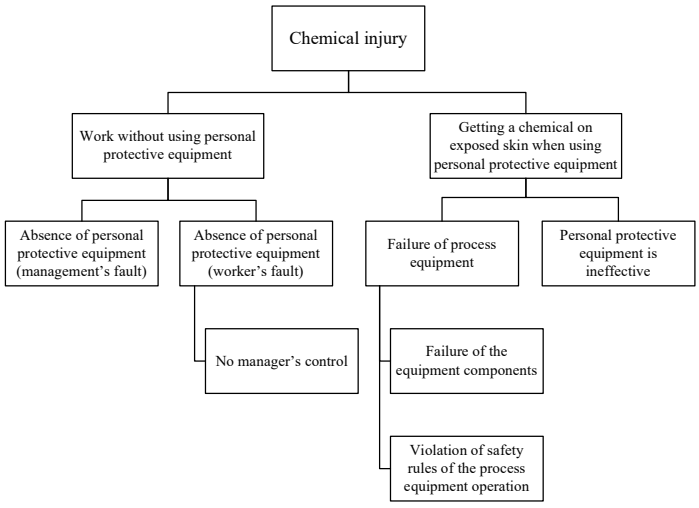

Figure 2 – Event tree for the chemical injury.

According to the event tree it can be concluded that the events leading to the realization of the accident depends on technical and organizational factors.

2.2. Recommendations on reducing risk of accidents in the cosmetic product manufacturer

To increase the effectiveness of occupational safety and health system and provide safe working conditions for staff, as well as reduce the risk of occupational injuries, the following organizational and technical actions should be performed:

- organization of periodic checks of expiration date and effectiveness of personal protective equipment;
- organization of staff occupational safety training in accordance with the decision of Russian legislation;
- organization of access control of people and motor transport to the company territory;
- providing conditions for the effective and continuous monitoring of the company area security.

In addition in order to avoid industrial injuries, occupational diseases and to minimize the impact of hazardous and harmful factors at the cosmetic product manufacture it is proposed introduce the following recommendations in the field of occupational safety and health management systems:

- to eliminate sources of hazards and reduce risk to an acceptable level;
- to limit the negative impact of hazards by using of collective protective equipment. For example: to use soundproof covers on the machines to reduce noise;
- to minimize the risk by designing process systems with a limited time of contact with harmful and dangerous process factors or to organize shift work for staff;
- to pay more attention to training of staff in accordance with applicable legislation and local regulations;
- not to neglect the use of personal protective equipment, including protective clothing, despite the fact that PPE do not eliminate the hazards however using it helps to reduce the negative impact of harmful factors down to acceptable.

To improve the overall level of safety should be also taken into account following organizational and technical actions:

1. Industrial safety:
   - carrying out a timely technical inspection of process equipment;
   - organization of effective control of the implementation of rules, regulations and guidelines;
   - organization of staff training in the field of industrial safety;
   - exclusion of the possibility of any unregulated work.
2. Fire safety:
   - organization of staff training in the field of fire safety;
   - fire prevention discipline at operation and maintenance of process equipment;
   - completion of the Russian legislation in the field of fire safety.
3. Ecological safety (according to Russian legislation): organization of development and coordination of environmental plan at the cosmetic product manufacturer.
4. Civil and territory protection (according to Russian legislation):
   - development a comprehensive plan of the company security improvement;
   - providing staff with personal protective equipment and its storage areas;
   - organization of training activities for staff to prepare their actions in the case of emergency;
   - organization and conducting of the trainings and alarms for the staff to provide possible actions in the case of accident;
   - audit of staff knowledge of the rules of action in the circumstances of the accident in the company.

3. Conclusion

In this paper we have realized the risk assessment at the cosmetic product manufacturer by expert judgement method. We have preliminary determined the possible accidents at the manufacturer. The data of experts' assessments is processed by statistical methods. Opinion consistency of experts is assessed by Kendall's coefficient of concordance. Significance of differences in accident risk assessments is estimated by Friedman ANOVA by ranks. The experts demonstrated appropriate consistency in their evaluation of risk. It is concluded that the risk of accidents is significantly different and the accident with the highest risk according to experts is the chemical injury. We have built and analyzed the event tree for the chemical injury. Based on the risk and event tree analysis we have offered organizational and technical actions to reduce the risk of implementation of occupational injuries.

References

[1] Villa V, Paltrinieri N, Khan F, and Cozzani V 2016 Towards dynamic risk analysis: A review of the risk assessment approach and its limitations in the chemical process industry *Safety Science* **89** 77
[2] Sengupta A, Bandyopadhyay D, Van Westen C J and Van Der Veen A 2016 An evaluation of risk assessment framework for industrial accidents in India *Journal of Loss Prevention in the Process Industries* **41** 295
[3] Khan F, Rathnayaka S and Ahmed S 2015 Methods and models in process safety and risk management: Past, present and future *Process Safety and Environmental Protection* **98** 116
[4] Garrick B J 1988 The approach to risk analysis in three industries: Nuclear power, space systems, and chemical process *Reliability Engineering and System Safety* **23**(3) 195
[5] Rosqvist T 2003 On the use of expert judgement in the qualification of risk assessment. *VTT Publ.* **507** 3
[6] Goossens L H J and Cooke R M 1997. Applications of some risk assessment techniques: formal expert judgment and accident sequnce precursors. *Saf. Sci.* **26** 35
[7] Paltrinieri N and Khan F 2015 Dynamic risk analysis in the chemical and petroleum industry (Elsevier)
[8] Reniers G L L 2010 A novel methodology for evaluating the change of existing operational staffing levels (MCSL) in the chemical industry *Safety Science* **48**(2) 179
[9] Goossens L H J, Cooke R M, Hale A R and Rodić-Wiersma L 2008 Fifteen years of expert judgement at TUDelft *Safety Science* **46**(2) 234
[10] Mannan S 2012 Lees' Loss Prevention in the Process Industries (Fourth Edition) vol 1 (Elsevier)